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International Institute
of Tropical Forestry

Research Map
IITF-RMAP-06

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Landscape units of Puerto Rico: Influence of climate, substrate, and topography

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English and Spanish version enclosed

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Project director: William A. Gould

The enclosed map was developed by the Puerto Rico Gap Analysis Project (PRGAP) and displays variation in the landscape related to climate, substrate, and topography. We have defined a set of 57 distinct landscape units by integrating six climatic zones (Holdridge lifezones), six geologic substrates, and five topographic positions. The map was developed for the purpose of understanding and modeling variation in vegetation. The map presents a set of ecologically distinct units and can serve as a tool for stratifying the landscape for assessing variation in ecosystem attributes and services.

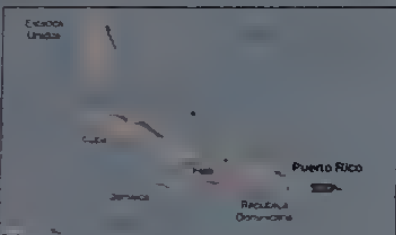
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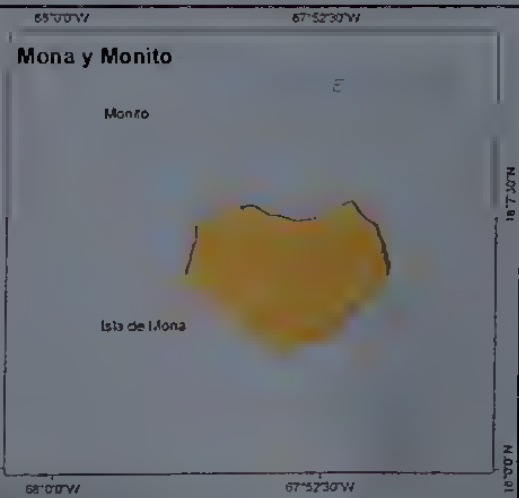
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Unidades del Paisaje de Puerto Rico: La influencia del clima, el substrato, y la topografía

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Desecheo



Descripción del mapa
El mapa de unidades del paisaje de Puerto Rico representa variaciones climáticas, topográficas y del substrato mediante la integración de seis zonas climáticas (Ewel y Whitmore, 1973), seis substratos (Bawiec, 2001; USGS, 2005), cinco posiciones topográficas, o topoformas (Martinuzzi et al. 2007), y cuerpos de agua (USGS 2005). Los substratos representan el conjunto simplificado creado por Bawiec (2001) compuesto por doce unidades de terrenos geológicos. Estos terrenos están clasificados en: depósitos de roca caliza del cretáceo y terciario, depósitos de aluvión y otros depósitos no consolidados del cuaternario, formaciones volcánicas intrusivas y extrusivas y depósitos sedimentarios volcánoclasticos (sedimentos de origen volcánico – pueden o no ser calcáreos), y formaciones de serpentina ultramáfica y anfibolito (bajo contenido de cuarzo, de pH típicamente alto). También se delinearon humedales salinos y no salinos (USGS 2005). El mapa resultante presenta 57 unidades del paisaje para las islas. El mismo fue desarrollado para el estudio y modelaje de la variación en la vegetación. La variación natural de la vegetación presenta una jerarquía de controles ambientales que incluyen clima, geoquímica de los substratos, topografía, y disturbios. La información geoespacial de estos controles es útil para modelar la variación de la cobertura vegetal y las propiedades de los ecosistemas asociados. Este mapa parte de trabajos previos por Figueroa (1996) para desarrollar un mapa de geoclima de Puerto Rico.

- Los controles climáticos incluyen el rango, la media, y la variabilidad de temperaturas del aire y precipitación regulada por gradientes latitudinales, patrones atmosféricos globales, patrones orográficos, y retroalimentación con la cobertura del terreno (Chapin et al. 2005).
- Las características del substrato (geoquímica) incluyen pH del suelo, disponibilidad de nutrientes, y textura, los cuales afectan fuertemente la composición de especies de plantas (Gould et al. 2006). La geoquímica esta relacionada a roca expuesta, depósitos cuaternarios, historia del uso del terreno, y procesos biológicos.
- La topografía afecta la composición de especies de plantas influenciando la humedad del suelo, desarrollo, textura, y química (Birkeland 1984). La posición de la pendiente esta también relacionada a disturbios. Topoformas particulares pueden estar influenciadas por inundaciones, tormentas, derrumbes, fuego, o disturbios antropogénicos.

Las topoformas más abundantes en Puerto Rico son las pendientes húmedas y muy húmedas en substratos volcánicos de la Cordillera Central y Sierra de Luquillo, las cuales representan 40% de la superficie de la isla. Pendientes húmedas y muy húmedas en substratos de caliza representan un 10% de la superficie. Lomas y pendientes secas representan un 6%, con 30% de las mismas en roca caliza, y el resto (70%) en substratos volcánicos y serpentina ultramáfica. Cerca del 12% del paisaje esta formado por aristas, del cual 90% están localizadas en regiones climáticas húmedas y muy húmedas. Los llanos húmedos representan un 16% y los llanos secos un 8% de la isla. Los humedales y las depresiones, sin incluir cuerpos de agua abiertos, representan un 5% de la superficie isla, 70% de de los cuales cuentan con un clima húmedo y 30% con un clima seco.



Unidades del paisaje
Estos datos son resultado de la integración de datos geoespaciales sobre topoformas y regiones geoclimáticas de Puerto Rico. Se derivaron 57 unidades del paisaje, incluyendo agua y cuatro tipos de humedales.

Topoformas
Las topoformas incluyen cinco posiciones de pendiente, modeladas utilizando elevación y topografía (Martinuzzi et al. 2007).

Clima y substrato
Las decisiones regionales geoclimáticas integran información de clima y geología utilizando las zonas de vida de Holdridge (Ewel and Whitmore 1973) y la geología de Puerto Rico creada por el Servicio Geológico de E.E.U.U.

Clima (Zonas de vida de Holdridge)

Caliza	Aluvial y cuaternaria no consolidada	Ultramáfica ígnea	Volcánica y volcánoclastica
Bosque seco subtropical	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano
Bosque húmedo subtropical	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano
Bosque muy húmedo subtropical	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano
Bosque pluvial subtropical	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano
Bosque muy húmedo montaño bajo	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano
Bosque pluvial montaño bajo	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano	Cresta Pendiente alta Pendiente baja Llano

Humedales y depresiones
Húmedo salino
Húmedo no-salino
Seco salino
Seco no-salino

Centros urbanos
Lagos
Ríos

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Chapin, F.S., III, M.J. Seneviratne, M.C. McFadden, J.P. Key, L.R. Lloyd, A.H. McGuire, A.D. Rapp, T.S. Linder, A.H. Schimel, J.P. Biringer, L. Chapman, W.L. Epstein, J. Roman, L.D. Jia, G. Jia, C.L. Jia, K.D. Thompson, C.D.C., Walker, D.A., Welker, J.M. 2005. Role of land-surface changes in arctic summer warming. Science 310: 957-960.

En el J.J. Whitmore, L.L. 1973. The Ecological Life Zones of Puerto Rico and the U.S. Virgin Islands. U.S. Forest Service research paper INT-48.

Figueroa-Colón J.C. 1996. Geoclimatic regions of Puerto Rico (map). U.S. Dept. Internat. Geol. Surv. Water Res. Div. San Juan, PR.

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Martinuzzi, S., Gould, W.A., Ramos-González, O.M., Edwards, H. 2007. Development of a landform model for Puerto Rico and its application for land cover change analysis. Caribbean Journal of Sciences 43:161-171.

USGS 2005. The National Hydrography Dataset (NHD). U.S. Geological Survey, Reston, Virginia.

Fuentes adicionales de datos
Centros urbanos: Los centros urbanos fueron desarrollados por el Laboratorio de SIG y Teledetección del Instituto Internacional de Dasonomía Tropical mediante la interpretación visual de mapas existentes. Cada punto representa la localización aproximada del centro urbano de cada municipio.

Datos hidrográficos: Los datos hidrográficos fueron derivados y generalizados de los datos del National Hydrography Dataset (NHD). El NHD fue creado por el U.S. Geological Survey en cooperación con el U.S. Environmental Protection Agency, USDA Forest Service, y otras agencias estatales y federales así como colaboradores locales. 2005, Reston, Virginia. Estos datos son presentados en formato vector, generalmente decimales a una escala de 1:24 000/1:12 000.

Geología: Los datos geológicos fueron derivados y generalizados de los datos. Terrenos geológicos de Puerto Rico (Bawiec, 2001).

Topoformas: Gould, W.A.; Martinuzzi, S.; Jiménez, M.E.; Edwards, B.R.; Ramos-González, O.M. 2008. Topographic units of Puerto Rico. Scale 1: 260 000. IITF-RMAP-04. Río Piedras, PR. US Department of Agriculture Forest Service, International Institute of Tropical Forestry.

Zonas climáticas: Modificado de Ewel y Whitmore (1973).

Cita sugerida
Gould, W.A.; Jiménez, M.E.; Potts, G.S.; Quiñones, M.; Martinuzzi, S. 2008. Landscape units of Puerto Rico. Influence of climate, substrate, and topography. Scale 1: 260 000. IITF-RMAP-06. Río Piedras, PR. US Department of Agriculture Forest Service, International Institute of Tropical Forestry. (Spanish version)

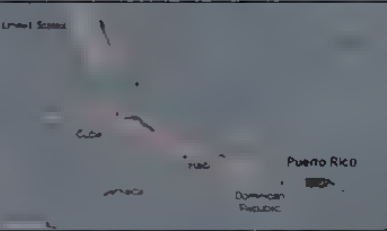
Agradecimientos
Esta investigación fue hecha con la ayuda y el apoyo de el USGS-BRB National Gap program (cooperative agreement No. 01HQPG0051 (01-1A-111201-002)), el Puerto Rico Gap Analysis Program (PRGAP), el Laboratorio de SIG y Teledetección del Instituto Internacional de Dasonomía Tropical, y el USDA Forest Service International Institute of Tropical Forestry.

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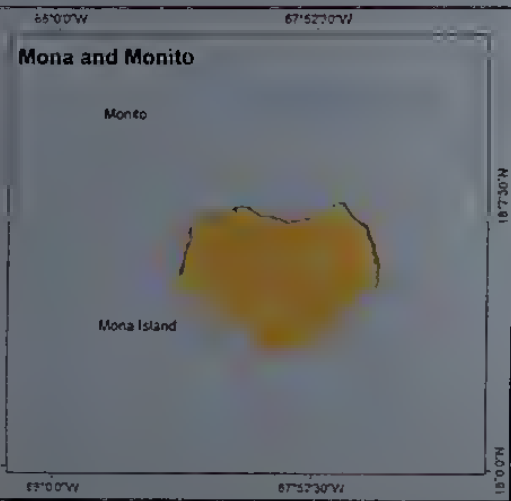
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Landscape units of Puerto Rico: Influence of climate, substrate, and topography

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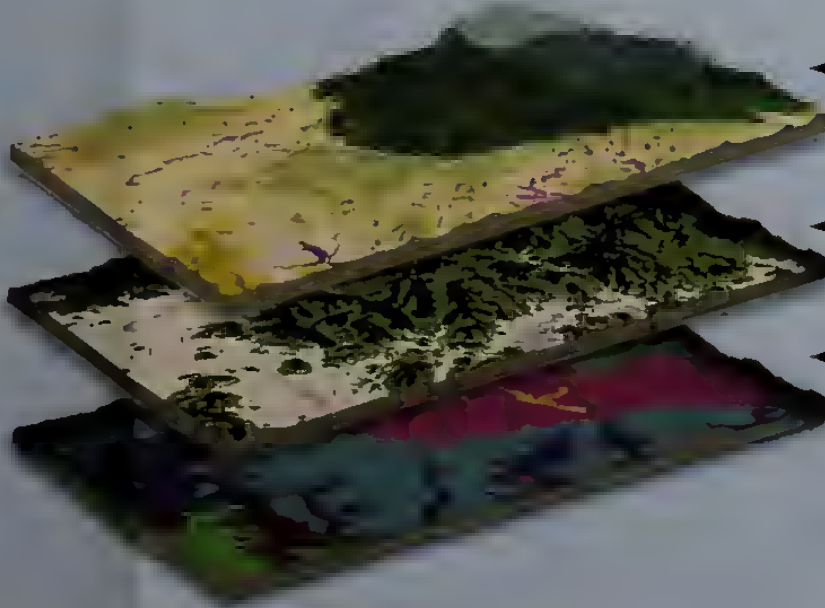
Desecheo



Map description
The landscape units map of Puerto Rico represents climatic, substrate, and topographic variation by integrating six climatic zones (Ewel and Whitmore 1973), six distinct substrates (Bawiec 2001, USGS 2005), five topographic positions or landforms (Martinuzzi et al. 2007), and prominent lakes and rivers (USGS 2005). Substrates were a simplified set of Bawiec's (2001) twelve geologic terrane units and include cretaceous and tertiary limestone deposits, alluvium and other unconsolidated quaternary deposits, intrusive and extrusive volcanic formations and volcanoclastic sedimentary deposits (reworked sediments of volcanic origin – may or may not be calcareous), and ultramafic serpentine and amphibolite formations (low quartz content – typically high pH). We also delineated saline and nonsaline wetlands (USGS 2005). The resulting map displays a set of 57 landscape units for the islands. The map builds on earlier work by Figueroa (1996) mapping geoclimatic variation in Puerto Rico and was developed for the purpose of understanding and modeling variation in vegetation. Natural variation in vegetation has a hierarchy of environmental controls, including climate, geochemical substrates, topography, and disturbance. Geospatial information on these controls is useful for modeling potential variation in vegetation cover and associated ecosystem properties.

- Climatic controls include the range, mean, and variability of air temperatures and precipitation regulated by latitudinal gradients, global atmospheric patterns, orographic patterns, and feedbacks with landcover (Chapin et al. 2005).
- Substrate characteristics (geochemistry) include soil pH, nutrient availability, and texture, which strongly affect plant species composition (Gould et al. 2006). Geochemistry is related to exposed bedrock, quaternary deposits, land use history, and biological processes.
- Topography affects plant species composition by influencing soil moisture, development, texture, and chemistry (Birkeland 1984). Slope position is also related to disturbance and particular landforms may be more or less influenced by flooding, storms, landslides, fire, or human development.

The most abundant landforms in Puerto Rico are the moist and wet slopes on volcanic substrates of the Central and Luquillo Mountains, which include 40% of the area. Moist and wet slopes on limestone substrates make up 10% of the area. Dry hills and slopes make up 6% of the area, with 30% of these on limestone and the remaining 70% on volcanic and ultramafic serpentine substrates. Nearly 12% of the landscape is made up of ridges and 90% of these are in the moist and wet climatic regions. Moist plains include 16% of the area and dry plains include 8% of the area. Wetlands and depressions, not including open water bodies, make up 5% of the area. Nearly 70% of these are in moist climatic regions and just under 30% in dry climatic regions.



Landscape units
This dataset is the result of the integration of geospatial data on landforms and geoclimatic regions of Puerto Rico. We derived 57 classes including water and four types of wetlands.

Slope positions
The landforms dataset includes five slope positions modeled using elevation and topography (Martinuzzi et al. 2007).

Climate and substrate
Sixteen geoclimatic regions integrate climate and geologic information using Holdridge's lifezones (Ewel and Whitmore 1973) and the USGS (Bawiec 2001) geology of Puerto Rico.

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ATLANTIC OCEAN

CARIBBEAN SEA

Caja de Muertos

Substrate

	Limestone	Alluvial and unconsolidated quaternary	Ultramafic igneous	Volcanic and volcanoclastic
Subtropical dry forest	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain
Subtropical moist forest	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain
Subtropical wet forest	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain
Subtropical rain forest	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain
Lower montane wet forest	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain
Lower montane rain forest	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain	Ridge Upper slope Lower slope Plain

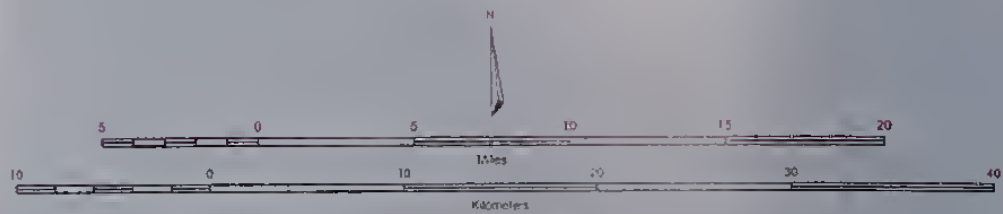
Wetlands and depressions
Moist saline
Moist non-saline
Dry saline
Dry non-saline

Lakes/Reservoirs
Rivers/Streams
Urban centers



PRGAP ANALYSIS PROJECT

IITF GIS and Remote Sensing Lab
A center for tropical landscape analysis



SCALE: 1: 260 000
Lambert Conformal Conic Projection
North America - Datum of 1983 UTM 18N

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Martinuzzi, S., Gould, W.A., Ramos-González, O.M., Edwards, B. 2007. Development of a landform model for Puerto Rico and its application for land cover change analysis. *Caribbean Journal of Sciences* 43:161-171.
USGS 2005. The National Hydrography Dataset (NHD). U.S. Geological Survey, Reston, Virginia.
Additional data sources
Climate (Holdridge lifezones): Modified from Ewel and Whitmore (1973).
Geology: The geology dataset was derived and generalized from the geologic Terranes of Puerto Rico by Bawiec (2001).
Hydrography data set: The hydrography dataset was derived and generalized from the National Hydrography Dataset (NHD). The NHD was originated by the U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency, USDA Forest Service, and other Federal, State and local partners. 2005. Reston, Virginia. This data set is presented as a vector digital data generally developed at 1:24,000/1:12,000 scale.
Landforms: Gould, W.A., Martinuzzi, S., Jiménez, M.E., Edwards, B.R., Ramos-González, O.M. 2008. Topographic units of Puerto Rico. Scale 1: 260,000. IITF-RMAP-04. Río Piedras, PR: US Department of Agriculture Forest Service, International Institute of Tropical Forestry.
Urban centers: This data set was developed by the GIS and Remote Sensing Lab of the International Institute of Tropical Forestry using visual interpretation of existing maps. Each point in the data set represents the approximate urban center for each municipality.
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Gould, W.A., Jiménez, M.E., Potts, G.S., Quinones, M., Martinuzzi, S. 2008. Landscape units of Puerto Rico: Influence of climate, substrate, and topography. Scale 1: 260,000. IITF-RMAP-06. Río Piedras, PR: US Department of Agriculture Forest Service, International Institute of Tropical Forestry.
Acknowledgements
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